RESEARCH NOTES

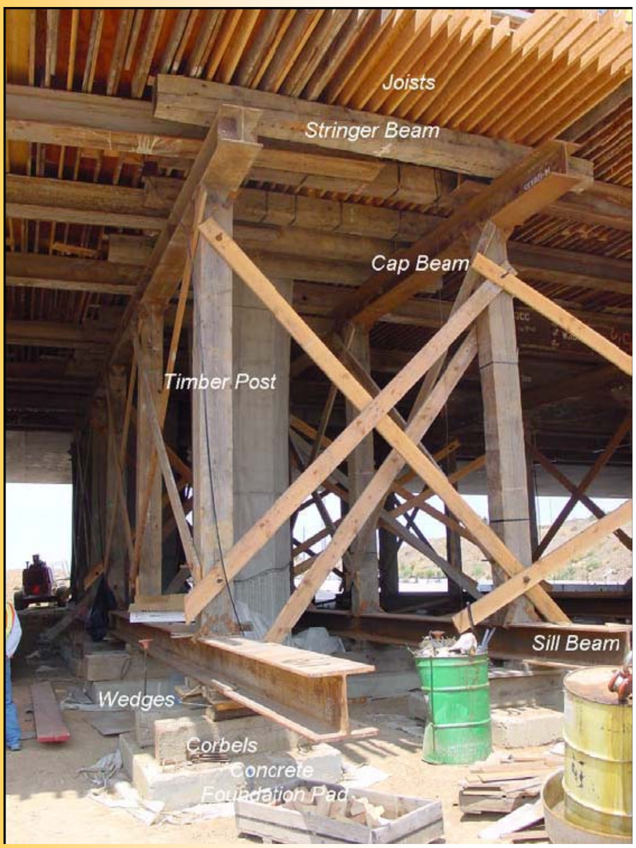
September 2006

Sill Beam Design and Capacity for Bridge Construction

RESULTS: ***Sill Beams are components used in the erection of cast-in-place concrete bridges. The result from research provides guidance to field engineers in identifying potential deficiencies resulting from localized bending in Cap and Sill Beams. Different methods are investigated for predicting the capacity of the steel flange. The research found lateral buckling and not web crippling dictated the failure mode and that blocking increased flange and web capacities. New design equations were derived this research to increase construction worker safety.***

Background

Construction Falsework in bridges typically consists of: timber or concrete foundations pads; timber corbels, sand jacks and wedges; steel sill beams; timber or round hollow steel posts; steel cap beams, timber or steel stringer beams and timber joists. These are stabilized for lateral loads using a series of timber or cable braces. An example of these components with steel posts and stringer beams is shown below. Historically failure of Falsework has occurred due to a number of causes. One cause could be localized flange bending at the interface between the cap and sill beams and posts.

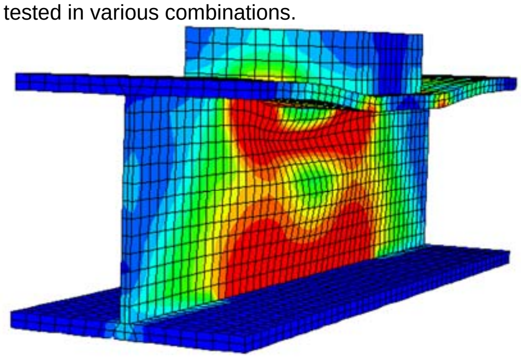


Why We Pursued This Research

The AISC LRFD specifications for structural steel buildings (AISC 2005) allows for the calculation of flange bending capacity in beam column joints. The ultimate load in the column flange assumes that a tensile line load is applied to the column flange from the beam flange. A yield line pattern in the column flange and a uniform stress distribution from the beam flange is then assumed in order to calculate the ultimate capacity of the flange. This equation is very conservative if applied to flange bending from compressive patch loading as the region of flange available to resist the load is much greater for a patch load than a line load and a compression load allows large stresses around the web. Past studies on the effect of patch loading have generally assumed rigid patch loads which have not resulted in flange bending other than that required for deformation of the web. A rigid patch load is defined as one where the patch load does not deform resulting in a redistribution of stresses if the loaded member deforms. This is in contrast to a flexible patch load which deforms as the loaded member deforms resulting in a more constant distribution of stresses. The case of a flexible patch load provided by a timber post has not been considered and, therefore, there is no method for predicting the resulting capacity of the beam flange. This research investigates the effect of patch loads from timber and steel posts on bending of the beam flanges, yielding or crushing of the posts, and yielding, crippling or lateral buckling of the web.

What We Did

Office of Earthquake Engineering from Engineering Service Center contracted with University of Nevada, Reno conduct research on Sill Beams in determining capacity. In addition to the coupon and components tests, eighteen (18) steel beams in four different sizes (HP12x53, HP14x73, W14x73, and W14x90) were tested in various combinations.



Test Matrix

Section		HP12x53			HP14x73			W14x90					
Post Type		None	Timber	Timber	None	Timber	Timber	None	Timber	Timber	Steel	Timber	None
Corbels		None	2 Timber	2 Steel	None	2 Steel	2 Steel	None	2 Timber	2 Steel	3 Timber	2 Steel	None
Lateral Restraint		Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No
Nominal Eccentricity = 0	No Blocking	10	12	18	9	20	29	6	1	22	2	26	5
	Blocking		13	19		21	30			23		28	
Nominal Eccentricity = bf/12	No Blocking			16									
	Blocking			17									
Nominal Eccentricity = bf/6	No Blocking	11		14	8	27	31	7	4	24	3		
	Blocking			15		25	32						

Research Results

- The following conclusions are drawn from the experimental and finite element studies are:
- The axial compression failure stresses of three 4 ft. long, 12 x 12 in. Number 2 Douglas Fir timber posts ranged between 1670 and 2770 psi.
- The axial bearing strength perpendicular to the grain for a 12 x 12 in Number 2 Douglas Fir timber corbel is 540 psi.
- The axial compression failure stresses of three 12 to 14 in. long, 12 x 12 in. Number 2 Douglas Fir timber blocks ranged between 3220 and 4820 psi.
- The steel sections had material strengths around 0 to 12% percent greater than the minimum specified yield stress.
- Sill beams and short timber posts with timber corbels typically fail through crushing of the corbels and possible bending of the flange adjacent to the corbel.
- Without timber corbels, sill and cap beams and timber posts typically fail through bending of the flange and localized of the post.
- Steel post joint regions typically fail though localized yielding of the post in the region where the post is bearing onto the beam flange near the web.
- If the post applying the patch loading has sufficient capacity and rigidity, a beam with a relative thick web is likely to fail by web yielding, with post-elastic crippling occurring after the yielding. Web yielding is most likely to govern over web crippling for typical Falsework beams.
- Unbraced, unstiffened beams may fail through lateral buckling of the web, particularly double stacked beams.
- Blocks placed between the flanges and web may increase the flange bending and web yielding capacity of the beam, although their effect in increasing lateral buckling capacity is inconclusive.
- An eccentricity between the flange and post of around 3 times the web thickness reduces the flange bending, yielding and buckling capacity by around 10%.

Recommendations

- Cap and sill beams should be designed for lateral buckling using the equation proposed based on a column buckling equation. If double stacked sill beams are used, the web height should be taken as the summation of the corresponding heights from the two beams. Bracing or fully welded stiffeners should be used in the cap and sill beams at the post locations if necessary to increase the lateral web buckling capacity. The radius of gyration in the equation can be increased accordingly.
- Cap and sill beams should be designed for web yielding using a 1:1 stress gradient through the flange. This uses the same equation as currently in the Falsework manual, although the name “web crippling” should be changed to “web yielding” to be consistent with AISC specifications.
- The cap and sill beams should be designed for an interaction between flange bending and post crushing when a timber post is used.
- A steel post should be designed for localized yielding where the ends of the post bearing onto the adjacent beams using a similar expression to that for web yielding.
- The timber and steel posts need to be designed for axial loads based on their length as ordinary columns. For the timber post equations based on the NDS specifications are more conservative than the Caltrans Falsework specifications and are recommended based on the limited post experimental data. The plot showing the CP factor could be included to simplify the calculation. An allowable stress of 1000 psi is tentatively recommended for Number 2 Douglas Fir posts. For the steel post the AISC design equations would allow for smaller posts than the Caltrans specifications and are also recommended.
- The bottom flange of a sill beam should be checked for flange bending based on the proposed equation.
- The timber corbels should be designed for bearing using the current Caltrans allowable stress for timber members. The allowable stress perpendicular to the grain for Number 2 Douglas Fir members in the NDS specifications is unconservative compared to the experimental data.
- Blocking can be used to increase flange bending and web yielding capacity if necessary.
- Any eccentricity between the centroid of the beam and post should be minimized, but at most it should be no more than 3 times the beam web thickness, for a reduction in flange bending and web buckling capacity of no more than 10%.

Reference

Lyle P. Carden, Ahmad M. Itani, Gokhan Pekcan; “Recommendations for the Design of Beams and Posts in Bridge Falsework”, Final Report, January 2006.